

a thermal energy user if a "topping cycle" is used.² An efficiency standard must also be met for facilities using natural gas or oil. For topping cycles, this efficiency standard will depend on the amount of useful thermal energy output provided [18 CFR, §292.205].

In addition to placing QF requirements into standard offer contracts, utilities also commonly require that size and operating conditions be met. For example, the contract may limit the amount of generating capacity (i.e., MW) for which the utility will pay. Applicants are also usually required to provide some type of reliability guarantee (e.g., posting a bond), backed up by penalties or reduced payments for nonperformance. It should be noted that reliability guarantee requirements vary from state to state. Note that some standard offer contracts may be available only to projects such as renewable energy or waste-to-energy projects that have special advantages. Such programs can create additional incentives to develop landfill gas projects.

Executing a Standard Offer

The electric utility's supply planning or power purchase department can provide details about available standard offer contracts and current avoided costs. This information can then be used in project economic calculations to determine if the project is viable. Standard offers usually provide variable short-term and fixed long-term payment options. The developer should choose the option that produces acceptable economics and enables the project to meet financing requirements. Appendix C contains the executive summary of a representative standard offer contract that was issued by one utility.

If the landfill owner/operator determines that the project is feasible under the set rates and contract conditions, the standard offer contract can be signed. In most cases, however, the state regulatory authority will review and approve the executed contract before it takes effect.

8.1.2 Bidding/Negotiating a Power Sales Agreement (PSA) With an Electric Utility

If a suitable standard offer is not available, a PSA may be pursued either through a utility bidding process or by presenting an unsolicited offer to the utility. This section discusses how to successfully negotiate a PSA by describing: (1) the request for proposals process; (2) what to include in an offer; (3) how utilities judge offers; and (4) contract considerations.

The Request for Proposal (RFP) Process

Utilities constantly review their energy needs and plan for the future, and this is usually done through the development of an integrated resource plan. If an energy need is identified,

² A "topping cycle" first uses energy input to produce power, then the rejected heat is used to provide useful thermal energy. In a "bottoming cycle", the sequence of energy use is reversed. There is no operating standard for a bottoming cycle QF.

a utility will sometimes solicit bids from power producers to fulfill that need by issuing an RFP.³ Sometimes, an RFP will call for specific project types, such as renewables, although the majority of RFPs are all-source solicitations, meaning any technology bid is permitted.

A potential bidder must be aware of the specific type of electric capacity that a utility needs (i.e., baseload versus peaking capacity). Landfill gas projects are well-matched to utility baseload, or around-the-clock, needs, because landfill gas must be continuously recovered throughout the year to prevent migration and to efficiently operate the recovery equipment. In contrast, landfill gas projects are not compatible with peaking needs, or needs that occur only during the times of highest electric demand (typically 5 percent or less of the year). In a peaking project, most of the landfill gas would have to be flared, and the energy recovery project would be idle for the majority of the year.

Even when no RFP is outstanding, a project proponent can offer an unsolicited bid to the utility. In this situation, the project proponent would take the initiative to approach the utility (typically the supply planning or power purchase department) and present his or her project concept.

Bid Requirements

Bid requirements will determine the level of detail and the specific components to be included in a bid package. If an RFP is issued, the requirements are set by the utility, and its format must be followed. However, if an unsolicited bid is to be offered, there is some flexibility in format, although enough information should be included to allow the utility to make a judgement. A complete bid document is comprised of many components which describe and document the various aspects of a project. The most important aspects are pricing, equipment description, and contract terms. Standard bid components for RFP responses are outlined in Table 8.1.

Before compiling the separate components of a bid document, the bidder should identify the project's competitive advantages. A good way to do this is to first prepare a project summary that sets the tone for the whole bid. By keeping the project's competitive advantages in mind throughout the bid preparation process, each component can be integrated to enhance the entire bid. Examples of a landfill gas project's potential competitive advantages are listed in Box 8.1.

Bid Evaluation Process

Cost will likely be an overriding factor when the utility is judging a bid, and landfill gas projects may have to compete against a utility's self-build option or a conventional natural gas-fired project. Additional non-price factors that impact bid evaluation and may benefit landfill gas projects include: societal benefits, environmental benefits, location, project timing, reliability, and risks.

³ Developers often study a utility's integrated resource plan (IRP) to anticipate upcoming capacity needs and solicitations. The electric utility and state regulatory authority can usually provide copies of the IRP.

Contract Considerations

The economic terms of a PSA are vital to a project; however, other contract terms and conditions affect the long-term viability and liability of the project as well. The entire contract offered by a utility should be carefully reviewed by the project developer and reliable legal counsel to ensure that each of the terms is acceptable. If they are not, a more acceptable, revised version of the contract should be presented to the utility for negotiation.

Primary contract considerations include:

Term — The contract term should be sufficient to support financing and/or the life of the project. A satisfactory term is usually 15 years or more [Knapp, 1990].

Termination — Grounds for contract termination should be very limited in order to protect the long-term interests of all parties.

Assignment — The contract should contemplate assignment for purposes such as financing. For example, allowing for contract assignment to a subsidiary or to partners may be advisable to avoid ownership arrangement difficulties [Knapp, 1990].

Force majeure⁴ — Situations that constitute force majeure (e.g., storms, acts of war) should be agreed upon, otherwise this clause could be used to interrupt operations or payment.

Schedule — There should be some flexibility allowed for meeting milestone dates and extensions (e.g., in penalty provisions). This is necessary in case unforeseen circumstances cause delays.

Price — The contract price should ensure the long-term viability of the project, which means that accounting for potential cost escalation through the contract will be very important. An example price structure that can be negotiated to accomplish this is multi-part pricing, described in Box 8.2.

⁴ A *force majeure* clause provides for situations that occur when circumstances beyond the control of either party disrupt normal operations. Penalties may be waived or reduced during force majeure events. Examples of force majeure events are earthquakes, hurricanes, strikes, riots, and acts of war.

Box 8.1 Multi-Part Pricing

A multi-part pricing scheme is one way to ensure long-term project viability by matching revenues with project expenses. The objective of this price structure is to ensure coverage of fixed costs (e.g., debt payment, fixed O&M), regardless of how often the project is called upon to run. The utility's decision to run the project is based on how the project's energy costs compare to those of other generating sources (in the case of landfill gas projects, these costs are very low, thus encouraging high levels of operation). A multi-part price contains two or more of the following components:

Capacity payment (\$/kW) — This fixed payment is based on the capital costs of the project. The payment should be high enough to ensure that the project can meet its debt service and equity return requirements, regardless of how often the utility chooses to run the project.

Energy payment (\$/kWh) — A variable energy payment is usually tied to fuel costs, which are very low for landfill gas projects.

Operation & Maintenance (\$/kWh and/or \$/kW) — This is a variable and/or fixed payment, which covers O&M costs of the project.

Start-up payment (\$) — A fixed price is sometimes paid to the project each time it is called upon to run. It covers the costs of start-up (e.g., electric demand costs, equipment wear).

8.1.3 Bidding/Negotiating a PSA with an End User

Some state regulatory authorities will allow non-utility power projects to make electricity sales directly to end users. However, such sales, when permitted, are typically limited to a number of contiguous neighbors.⁵ In the near future, unconditional sales to retail end users may be permitted as a result of deregulation in the electric industry. When end user sales are sought, it is up to the landfill gas power project to negotiate contract terms and conditions with the customer.

When negotiating an end user PSA, it will likely be necessary to offer the customer an electricity rate that provides a discount over the rate currently paid to the local utility (i.e., a rate based on the customer's avoided cost). Since retail electric rates are typically higher than the buyback rates available from utilities, this type of displacement arrangement can be very attractive to both the buyer and seller. For example, in 1992, the average posted U.S. retail electric rate to industrial customers was ¢4.8/kWh; commercial rates averaged ¢7.6/kWh for the same period [Energy Information Administration, 1994]. In comparison, average 1992 utility avoided cost buyback rates ranged from ¢2.9/kWh to ¢3.5/kWh [ICF, 1994].

⁵ Because state regulatory policies vary, it is essential that landfill owners/operators contact authorities to determine any limitations or conditions governing direct electricity sales to end users before trying to negotiate a PSA.

Table 8-1 Typical Bid Components

BID COMPONENT	DOCUMENTATION CHECKLIST
Siting	<ul style="list-style-type: none"> • map, showing site location (e.g., USGS map) • site plan • purchase option agreement (if necessary) • description of rights-of-way (if applicable) • environmental assessment
Electric Interconnect	<ul style="list-style-type: none"> • load flow study (if required) • location of point of interconnection
Technology	<ul style="list-style-type: none"> • project design configuration • equipment specifications • technology status, experience • vendor guarantees (performance, timing, cost)
Fuel Supply	<ul style="list-style-type: none"> • reports on viability of field (reliability is key) • cost, fuel price escalation • documentation of long-term supply (historical data) • documentation of gas rights
Experience	<ul style="list-style-type: none"> • description of developer experience
Timing	<ul style="list-style-type: none"> • timeline for permitting, construction • commercial operation date
Permitting	<ul style="list-style-type: none"> • zoning plan • air plan • water plan
Financing	<ul style="list-style-type: none"> • plan • debt coverage ratios • pro forma
Pricing	<ul style="list-style-type: none"> • breakdown of project cost • capacity • energy • indices (e.g. fuel price escalation)
Regulatory Status	<ul style="list-style-type: none"> • FERC QF filing • agreement with steam host (if applicable)
Operation & Maintenance	<ul style="list-style-type: none"> • maintenance schedule • flexibility
Contract Terms	<ul style="list-style-type: none"> • marked-up contract terms (see section on contract considerations)

Box 8.2 Potential Competitive Advantages of Landfill Gas Projects

- Landfill gas comes from one local source, and it usually costs less than conventional fuels.
- Landfill gas energy recovery is a proven technology. Operators and equipment manufacturers have gained experience with the conversion technologies used in landfill gas recovery operations.
- Landfill gas recovery projects provide a net environmental benefit by reducing methane and volatile organic compounds emissions, conserving fossil fuels, reducing explosive hazards, and reducing odor. In addition these benefits ease the permitting process, may be shared with the utility, or used as a bargaining chip.
- Most landfill gas projects are situated at a landfill site, which may ease or eliminate local permitting and zoning requirements.
- The price of fuel and equipment is fixed at the project outset; there is only minimal price escalation.
- Landfill gas projects can serve on-site electrical loads at dispersed locations, thus reducing the need for new generating plants and transmission facilities.
- Landfill gas projects offer a way for utilities to attain Climate Challenge voluntary greenhouse gas emission reduction targets.
- Title IV of the Clean Air Act (Acid Rain Program) creates a quantifiable value for avoided SO₂ emissions. Each ton of SO₂ avoided through generation of electricity from landfill methane saves one emission allowance for utilities affected by Title IV. For those utilities not affected until the year 2000, each 500 MWh of electricity produced by landfill gas may be worth one "bonus" allowance (currently at \$150 each). See Appendix I.

The basic contract terms and conditions to be considered when negotiating a PSA with an end user will be the same as those outlined above for a utility PSA: term, termination, assignment, force majeure, schedule, and price. Also, it is usually desirable to use a multipart price structure (see Box 8.2), even with non-utility customers. The concept should not be foreign to industrial and commercial facilities, because electricity and gas are commonly purchased under a tariff that includes an energy component, demand component, and customer charge.

8.1.4 Wheeling Arrangements

A power project may be unable to obtain a favorable power sales contract with the utility to which it is directly interconnected. In such instances it may be possible for the project to transport, or "wheel," its power over the local utility's transmission system in order to sell to a third party. When wheeling is necessary to reach a buyer, arrangements must be made with

the local utility to specify the terms and conditions for the wheeling service.

The three basic types of wheeling services are: (1) wholesale; (2) self-service; and, (3) retail. As a result of recent regulation, all utilities will soon be required to provide wholesale wheeling to power producers at specified rates. However, self-service wheeling is currently only permitted in three states (Connecticut, Florida, and Maine) and retail wheeling is currently only allowed in very limited circumstances in Nevada.

Wholesale Wheeling

Wholesale wheeling occurs when a utility transports power over its transmission system for delivery to another utility. All utilities may soon be required by FERC to provide wholesale wheeling services to power projects; however, there is currently much debate about how to determine the rates charged for these services. It is important to keep in mind that the transmission rates will determine if it is economical to make off-system sales. For example, if it costs ¢4.7/kWh to produce electricity and ¢2/kWh to transport it to the buyer, then the total delivered electricity cost of ¢6.7/kWh may not be low enough to justify the sales transaction.

Self-Service Wheeling

If a landfill gas owner/operator wants to deliver power to another of its facilities located elsewhere on the local utility's system, then it may be possible to have the utility transport the project's output to the site on behalf of the landfill owner/operator. For example, if a county that owns the local landfill, the county prison facility, and various other office buildings located around town then develops a power project at the landfill site, it could arrange to have the local utility transport (i.e., wheel) the electricity from the project to the prison and courthouse. This type of transmission service is known as self-service wheeling.

Currently, only three states — Connecticut, Florida, and Maine — permit self-service wheeling. However, self-service wheeling has never been tried in some states, so if it is beneficial to a project, then the landfill owner/operator should contact state regulatory authorities to determine if it would be permitted.

Retail Wheeling

In the future, there may be expanded opportunities for power projects to make sales directly to retail end users such as industrial facilities, hotels, and commercial buildings. Currently, "retail wheeling", which means the sale of electricity directly to a retail customer using the local electric utility's transmission lines, is prohibited in most states. The concept of retail wheeling includes transmission service, which sets it apart from on-site electric sales from a power project to an adjacent facility. Retail wheeling is currently allowed in Nevada under limited circumstances, Michigan will soon begin a retail wheeling experiment, and California has proposed regulations which would permit retail wheeling for some customers beginning in 1996. Several other states are also considering the issue. On-site electric sales to adjacent facilities are allowed under certain circumstances in several states. In addition, some utilities are beginning to launch pilot programs under which retail wheeling is allowed. The possibility of direct sales to distant or adjacent facilities represents an important future opportunity, since the revenues from retail electricity buyers would most likely be higher than is available from wholesale (i.e., utility) buyers.

8.2 GAS SALES CONTRACT (MEDIUM OR HIGH-BTU)

Gas sales contracts are a product of successful negotiation between the landfill gas project developer and the gas user or distributor. When negotiating a contract, it is important to keep in mind the project's requirements (i.e., revenue, operational considerations), while at the same time knowing where compromises can be made to accommodate the customer's needs.

Figure 8.3 outlines the steps involved in winning a gas sales contract. As illustrated, customer needs and contract considerations will vary, depending on whether the gas product to be sold is medium-Btu or high-Btu gas. Medium-Btu sales contracts are obtained with direct use customers, such as industrial companies or commercial complexes, whereas high-Btu contracts are typically negotiated with local gas distribution companies. Customer proximity is a primary factor in determining the feasibility of either type of project.

8.2.1 Medium-Btu Gas Sales

Medium-Btu sales contracts are usually unsolicited and initiated by the developer. Negotiations for a contract should begin with a potential gas customer (as represented by a plant manager or plant engineer) during initial feasibility studies. It is important that the developer obtain an initial indication of the price and terms that the gas customer is willing to accept, so that they can be taken into consideration during later contract negotiations. Usually these are dependent on the price and delivery terms of the existing or alternate fuel supply.

Specific contract items which document each party's responsibility and limit landfill liability and risk exposure are:

Gas price — This \$/MMBtu price could include fixed and variable components.

Equipment retrofit/modifications — It should be clear who is responsible for the capital cost of any required changes to the gas purchaser's equipment; this will avoid any confusion or misunderstanding between parties.

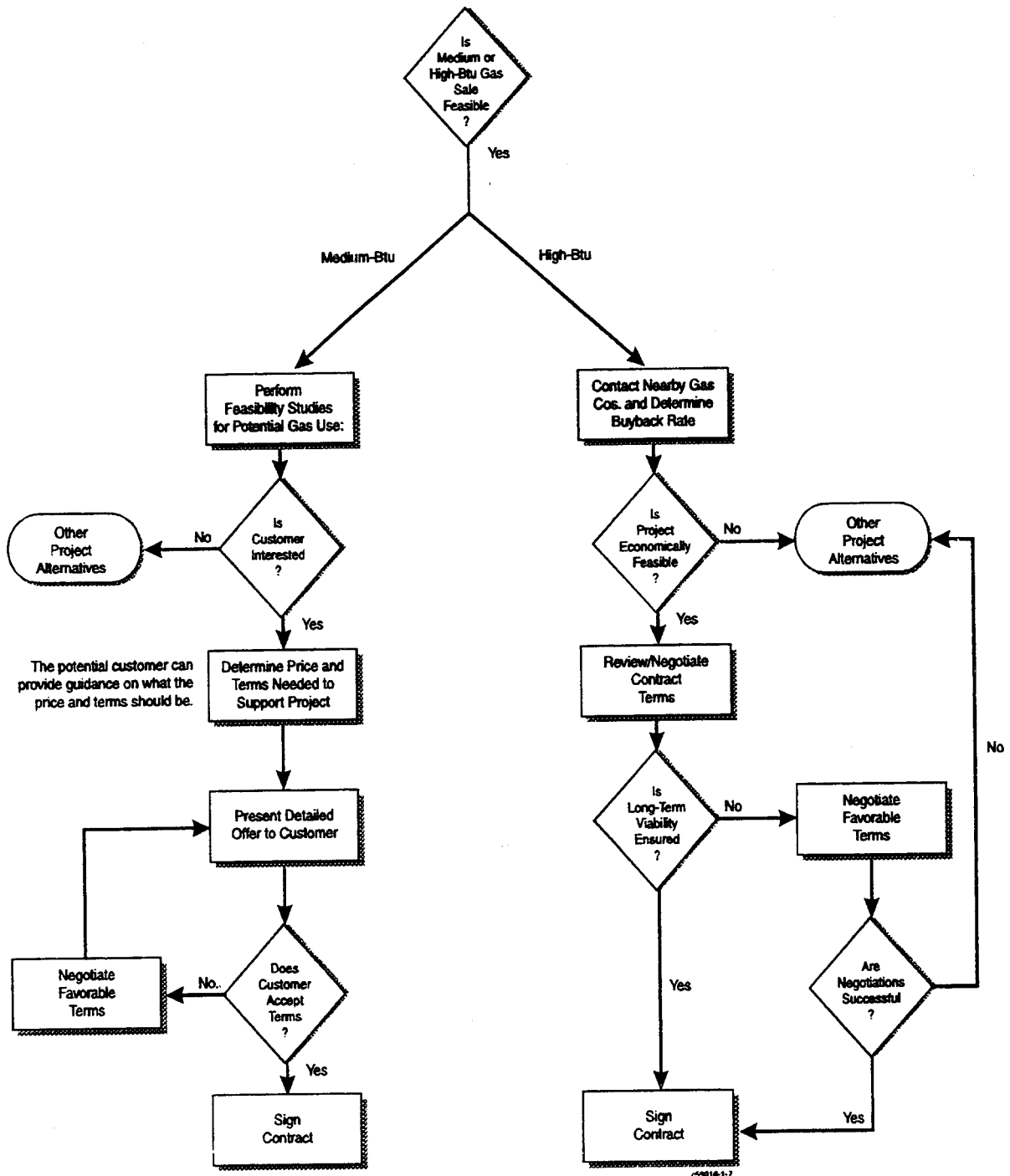
Pipeline construction and maintenance — Frequently, a dedicated pipeline will be required to transport the landfill gas from the site to the customer. Responsibility for pipeline construction costs and O&M should be clearly defined, which will help ensure that the pipeline is completed on time and is properly maintained.

Minimum purchase amounts — The amount (daily, annual, or total) of gas that the customer is required to buy, and that the landfill is required to provide, should be set, with some tolerances allowed. This will help to define the size of the project and will ensure revenues.

Changes in purchase amounts — The situation in which either party wishes to increase/decrease purchase amounts should be addressed, with flexibility allowed (e.g., decrease in landfill gas production or plant needs).

Alternate fuel — If a backup, or secondary, fuel is required to operate the gas purchaser's equipment, then the contract should clearly define who is responsible for purchasing the fuel under a variety of circumstances (e.g., landfill is responsible if production falls due to well maintenance problems).

Figure 8-3 Winning/Negotiating An Energy Sales Contract (Gas Sales)



8.2.2 High-Btu Gas Sales

Local distribution companies (LDCs) require a reliable supply of natural gas to serve their customers, and they have a variety of supply contracts in place to meet these needs. Some are long-term, while others only last for periods of one month or less. Contracts that provide price stability and supply reliability are attractive. Landfill gas can provide both, and may therefore have an advantage over conventional natural gas supplies if the energy recovery project is economic.

Some LDCs occasionally request proposals for gas supply packages; however, it is unlikely that an RFP process will be used to obtain a high-Btu sales contract. The best way to obtain a contract is to first contact the LDC's gas supply department to determine pricing options. If the project is economically viable given the LDCs projected buyback rates, further consideration should be given to specific contract terms.

Things to consider in negotiating a contract with an LDC include:

Take-or-pay clauses — It will be advantageous to the project if the utility is required to pay for a set amount of gas even if it does not take delivery; however, the LDC will likely resist such a clause.

Interconnect costs — The responsibility for the cost of construction and maintenance of interconnect facilities (e.g., pipelines, connections, metering, pressure regulation, filtering, moisture removal) should be clearly delineated. Pass-through to the gas seller of taxes assessed on construction costs are an especially important issue with interconnects, since project configuration may determine their applicability.

Gas pressure and quality requirements — These must be defined at the outset, as they will determine the amount of gas processing needed. This is important for landfill gas projects because gas compression and enrichment are expensive.

Standby or non-performance clauses — These should be defined at the outset as they will determine any fines or penalties that are incurred as a result of non-compliance with the contract.

Terms and times of delivery — The amount (daily, annual, or total) and times of delivery of gas that the customer is required to buy, and that the landfill is required to provide, should be set, with some tolerances allowed.

9. SECURING PROJECT PERMITS AND APPROVALS

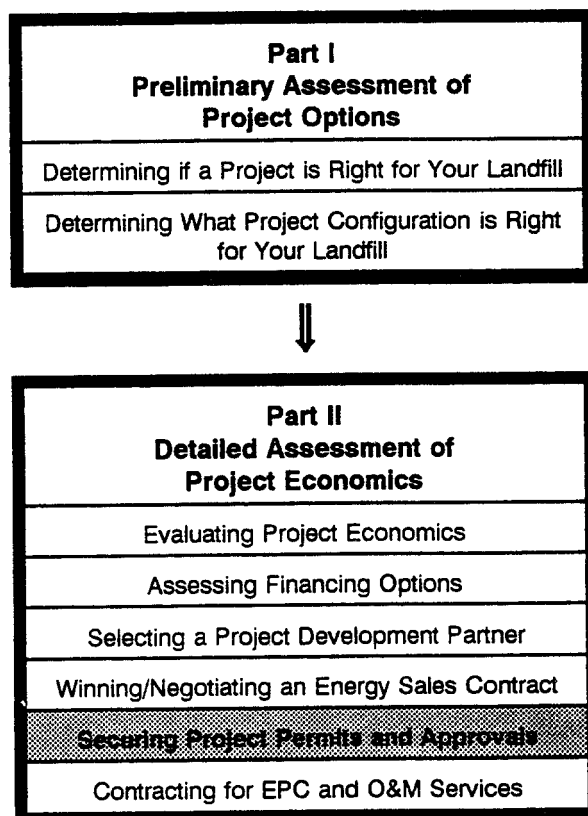
Obtaining required environmental, siting, and other permits is an essential step in the development process. Permit conditions often affect project design, and neither construction nor operation can begin until all permits are in place. The process of permitting a landfill gas-to-energy project may take anywhere from six to eighteen months (or longer) to complete, depending on the project's location and recovery technology. For example, a project sited in a location that requires no zoning variances and that meets national air quality standards will probably take much less time to permit than a project subject to zoning hearings and stringent air quality requirements.

Landfill gas energy recovery projects must comply with federal regulations related to both the control of landfill gas emissions and the control of air emissions from the energy conversion equipment. Regulations promulgated under two separate federal acts specifically address emissions from municipal solid waste landfills:

- Resource Conservation and Recovery Act (RCRA) regulations focus on landfill gas hazard and nuisance abatement [40 CFR, §258.23].
- Clean Air Act regulations focus on control of landfill gas emissions [61 FR 9905, March 12, 1996].

Air emissions from energy recovery projects are addressed in other sections of the Clean Air Act. This chapter briefly discusses these major federal regulations and their impacts on landfill gas energy recovery projects. It should be noted that states are generally granted the authority to implement, monitor, and enforce the federal regulations by establishing their own permit programs. As a result, some state permit program requirements are more stringent than those outlined in the federal regulations and there is a large state-to-state variance in agencies and standards. For this reason, landfill owner/operators and project developers should determine state and local requirements before seeking project permits.

The Project Development Process



9.1 THE PERMITTING PROCESS

There are four general steps (outlined in the flowchart in Figure 9.1) that will help ensure that the necessary permitting requirements under applicable state and federal regulations are met:

Step 1. Hold preliminary meetings with key regulatory agencies. Discuss with regulators the requirements and issues they feel must be addressed. These meetings also give the developer the opportunity to educate regulators about the project, since, in many cases, landfill gas-to-energy technologies may be unfamiliar to regulators.

Step 2. Develop the permitting and design plan. Determine the requirements and assess agency concerns early on, so permit applications can be designed to address those concerns and delays will be minimized.

Step 3. Submit timely permit applications to regulators. Submit complete applications as early as possible to minimize delays.

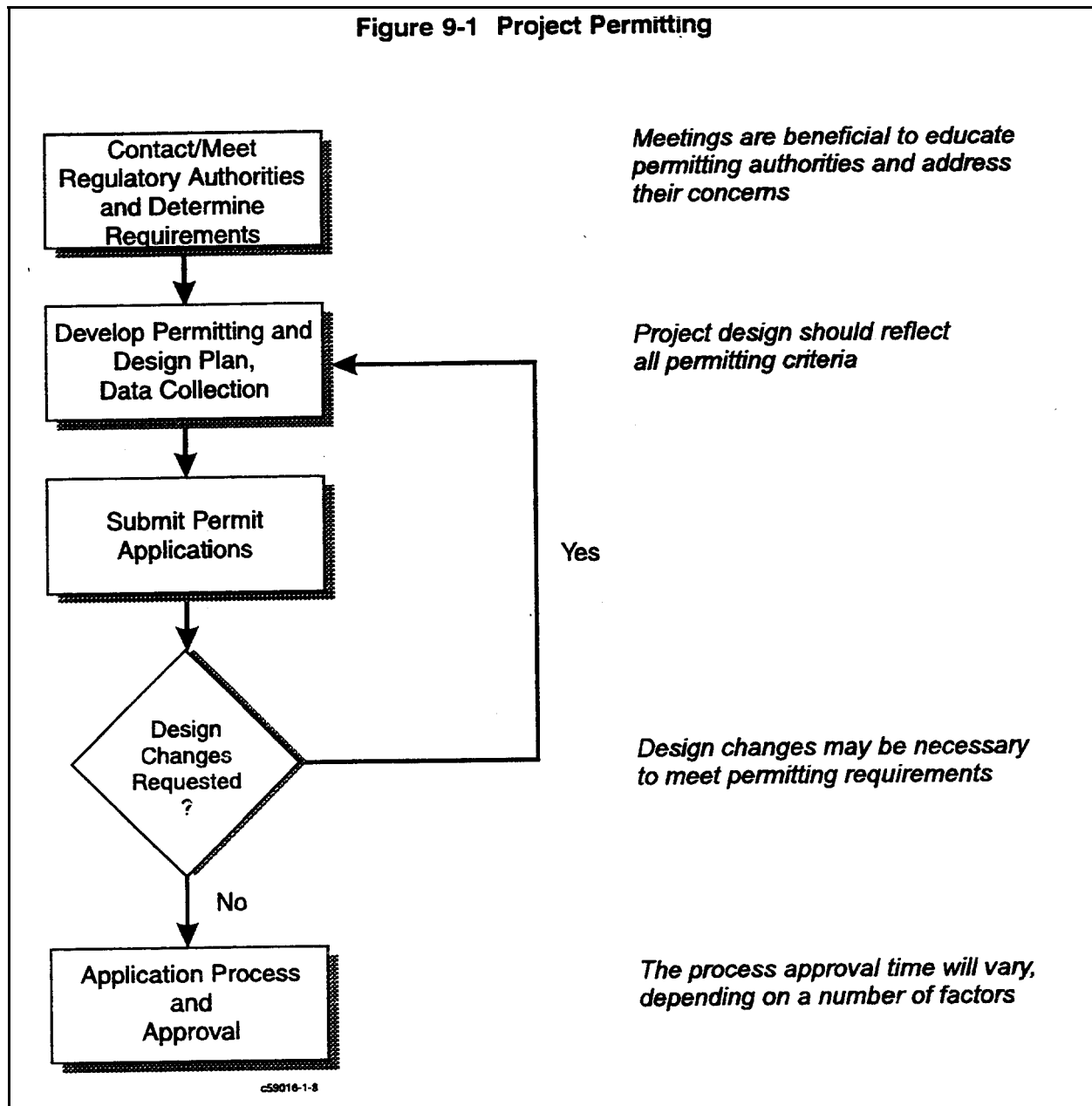
Step 4. Negotiate design changes with regulators in order to meet requirements. Permitting processes sometimes provide opportunities for project sponsors to negotiate the appropriate control measure and level with regulators. If negotiation is allowed, it may take into account technical as well as economic considerations.

As these steps indicate, the success of the permitting process relies upon a coordinated effort between the developer of the project and various local, state, and federal agencies who must review project plans and analyze their impacts. For landfill gas projects in particular, developers often must deal with separate agencies with overlapping jurisdictions over landfill operations and energy recovery operations (e.g., solid waste and air quality authorities). This underscores the importance of coordinating efforts to minimize difficulties and delays.

In some cases, permitting authorities may be unfamiliar with the characteristics and unique properties of landfill gas. Where appropriate, the landfill owner/operator or project developer should approach the permitting process as an opportunity to educate the permitting authorities, and should provide useful, targeted information very early in the process.

Emphasizing the pollution control aspects of landfill gas energy recovery projects can be an effective approach in seeking permits. If a landfill gas collection and flare system has not yet been installed or does not collect the full quantity of landfill gas emitted, then there is a substantial opportunity to reduce non-methane organic compounds (NMOC) and methane emissions from the landfill. An energy recovery project can further reduce these emissions by capturing additional landfill gas, as well as reducing emissions of carbon dioxide, sulfur dioxide, and other pollutants by displacing a fossil fuel source. Approaching and presenting the project as a pollution control project that will cause a net reduction in emissions can make the air permitting process much easier.

Figure 9-1 Project Permitting



9.2 RCRA SUBTITLE D

RCRA Subtitle D, established to ensure the protection of human health and the environment, sets minimum national design, operating and closure criteria for municipal solid waste landfills that were active on or after October 9, 1993. Virtually all currently operating municipal solid waste landfills are considered affected landfills under RCRA. Landfill gas control is one item addressed in the regulations.¹

¹ RCRA Subtitle D applies to affected landfills, regardless of whether an energy recovery project is in place.

Landfill gas control is achieved by requiring affected landfills to establish a program to periodically check for methane emissions and prevent offsite migration. Landfill owners or operators must ensure that the concentration of methane gas does not exceed: (1) 25 percent of the lower explosive limit for methane in facility structures (excluding gas control or recovery system components); and, (2) the lower explosive limit for methane at the facility boundary. Permitted limits on methane levels reflect the fact that methane is explosive within the range of 5 to 15 percent concentration in air. If methane emissions exceed permit limits, corrective action (i.e., installation of a landfill gas collection system) must be taken [40 CFR, §258.23]. Subtitle D may provide an impetus for some landfills to install energy recovery projects in cases where a gas collection system is required for compliance.

Subtitle D requirements for methane emissions monitoring affect landfills not only during operation, but also for a period of thirty years after closure.

9.3 CLEAN AIR ACT

The Clean Air Act (CAA) addresses landfill gas-to-energy recovery project emissions in two ways:

- (1) Regulation to control the emissions of non-methane organic compounds found in landfill gas, and
- (2) Regulation of airborne emissions from the combustion sources used in landfill gas energy recovery.

This section explains how the CAA regulations apply to and impact landfill gas energy recovery projects.

9.3.1 Landfill Gas Emissions

On March 12, 1996, EPA promulgated New Source Performance Standards (NSPS) and Emissions Guidelines (EG) for landfills under the authority of Title I of the Clean Air Act (61 FR 49, 9905, March 12, 1996). The regulations target landfill gas emissions because they contain nonmethane organic compounds (NMOCs), which contribute to smog formation. The requirements of the NSPS and EG are basically the same, with the main difference being the timing of implementation and the lead agency — the EPA administers the NSPS which takes effect immediately, while the states implement the EG once they have completed and received EPA approval of their implementation plans.

The regulations require landfill gas control at municipal solid waste landfills that meet all of the following criteria:

Age — The NSPS apply to all "new" landfills — i.e., those that began construction, reconstruction, or accepting wastes for the first time on or after May 30, 1991 (the date the proposed regulations were published in the Federal Register). The EG apply to "existing" landfills — i.e., those that accepted wastes on or after November 8, 1987. Both "new" and "existing" landfills are referred to below as "affected" landfills." Landfills that were closed prior to that date are not subject to the regulations.

Capacity — Affected landfills with a design capacity greater than 2,500,000 Mg (2,750,000 tons) are subject to the emission rate criterion described below.

Emission rate — Affected landfills meeting the capacity criterion must collect and combust their landfill gas if their maximum annual NMOC emission rate is greater than 50 metric tons. This emission rate can be determined either by desktop calculation using an EPA model (known as a Tier One analysis), or by EPA-defined physical testing procedures (known as Tier Two or Tier Three determinations).

Affected landfills that must collect and combust their landfill gas can use a flare system or an energy recovery system that has been demonstrated to reduce NMOC emissions by 98 percent. Landfill gas-to-energy should be evaluated at each landfill site to determine whether it is cost-effective, as it offers landfill owners an opportunity to mitigate the costs of compliance with the regulations. In addition to control requirements, the proposed regulations also contain recordkeeping and reporting requirements.

As the permitting process outlined in Figure 9.1 indicates, it will be important to contact regulatory authorities in order to determine and verify applicability criteria before developing a compliance plan. Appendix B is a list of regional and federal EPA offices that can provide detailed information about the regulations.

9.3.2 Regulations Governing Air Emissions from Energy Recovery Systems

Regulations have been promulgated under the CAA governing airborne emissions from new and existing sources. These regulations require new stationary sources and modifications to existing sources of certain air emissions to undergo the New Source Review (NSR) permitting process before they can operate.² The purpose of these regulations is to ensure that sources meet the applicable air quality standards for the area in which they are located. The applicable air quality standards are determined, in part, by the National Ambient Air Quality Standards (NAAQS), which have been set by EPA for six criteria air pollutants.

Two aspects of the NAAQS affect the stringency of the NSR permitting process. First, it sets overall regional ambient air loadings for the criteria pollutants. Using these levels, most areas of the country are classified as in "attainment" or "nonattainment" for each criteria pollutant. Areas that meet the NAAQS for a particular air pollutant are classified as in "attainment" for that pollutant, while areas that do not meet the NAAQS for a particular air pollutant are classified as in "nonattainment" for that pollutant. The same area may be in attainment for one air pollutant, but in nonattainment for another pollutant. Nonattainment areas are further categorized by their degree of nonattainment: marginal, moderate, serious, severe, and extreme. The greater the degree of nonattainment, the more stringent the regulations are in bringing that area to attainment and the lower the acceptable emission levels of particular pollutants will be. Some areas of the country are "unclassified" for all or some pollutants. An area that is listed as "unclassified" for a particular pollutant is one that has not had a project undergo the air permitting process for that pollutant.

² The EPA's NSR regulations for nonattainment areas are set forth in 40 CFR 51.165, 52.24 and part 51, Appendix S. The PSD program is set forth in 40 CFR 52.21 and 51.166.

Second, the NAAQS sets emission levels for new stationary sources and for modifications to existing sources. These levels are expressed in terms of total atmospheric loadings (i.e. tons emitted per year), as opposed to emission rates (tons/kwh), and are dependent upon location (attainment or nonattainment area) and the type of source (new or existing and its quantity of emissions). New sources or modifications to existing sources that exceed these NAAQS emission levels are classified as "major" sources while those that do not are classified as "minor" sources.

The principal air permitting requirements for landfill projects in attainment and nonattainment areas are described in detail below. As the discussion indicates, new stationary sources and modifications to existing sources in attainment areas undergo Prevention of Significant Deterioration (PSD) permitting while those in nonattainment areas undergo Nonattainment Area permitting. The basic difference between these processes is that the NSR permitting requirements are more stringent for major sources or modifications in nonattainment areas than for those same sources or modifications in attainment areas.

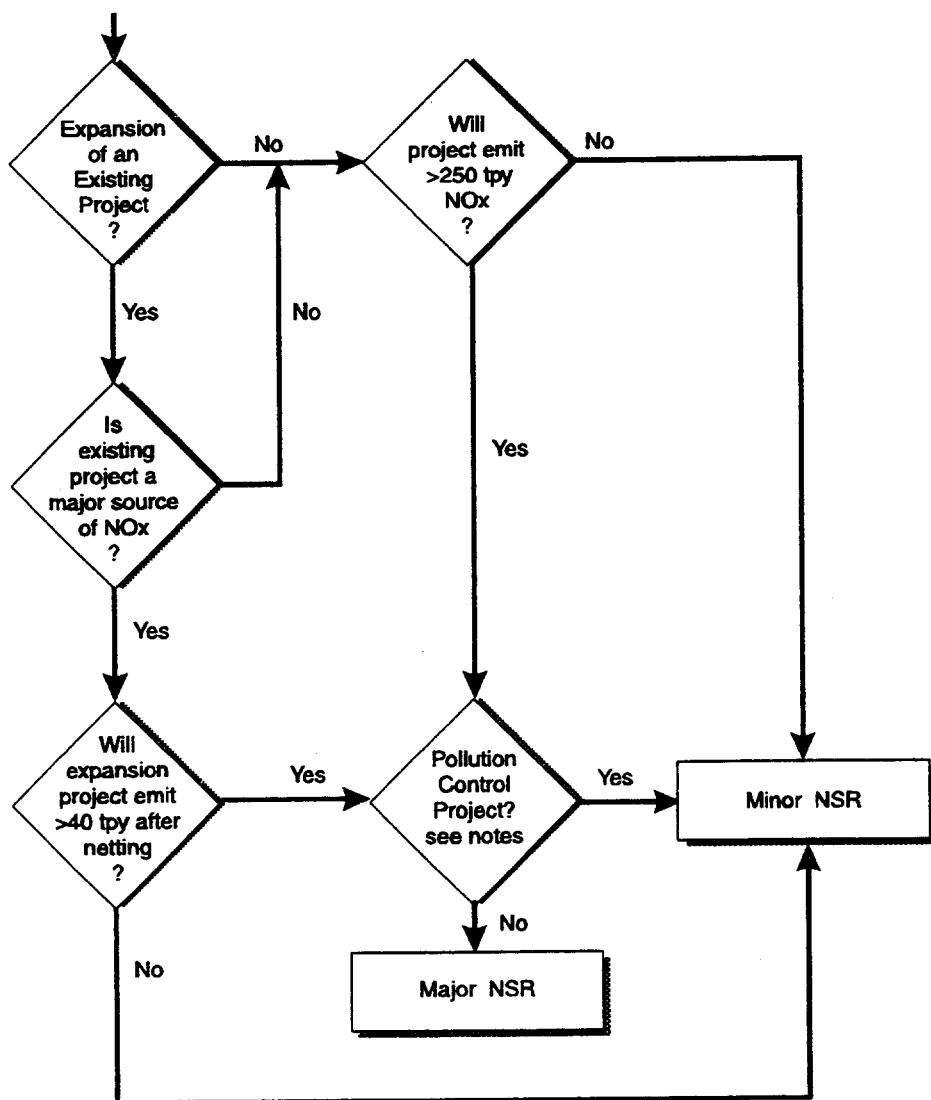
Most landfill energy recovery projects will likely be affected by the NAAQS standards for nitrogen oxides (NO_x) and carbon monoxide (CO). Whether a major NSR is required at a particular landfill project will depend on the level of emissions resulting from the project (which is primarily a function of project size and technology) and the project's location (attainment or one of the five degrees of nonattainment). As discussed below, small projects and/or those located in attainment areas may find the air permitting process to be quite straightforward (minor NSR), while larger projects, particularly those in nonattainment areas, may require major NSR, which is more extensive. In any event, given the complexity of the air permitting regulations, a landfill owner or operator may wish to consult a local attorney or other expert familiar with NSR permitting requirements in a particular area.

Attainment Area Permitting or PSD Permitting

PSD review is used in attainment areas to determine whether or not a new or modified emissions source will cause significant deterioration of local air quality. All areas are governed to some extent by PSD regulations because it is unlikely that a given location will be in nonattainment for all criteria pollutants. Applicants must determine PSD applicability for each individual pollutant. For gas-fired sources, including landfill gas energy recovery projects, PSD and major NSR is required if the new source will emit or has the potential to emit any criteria pollutant at a level greater than 250 tons per year. A modification to an existing emission source is considered major if one of the following conditions is met: (1) the existing source is already a major source of a particular air pollutant and the modification will emit that air pollutant at a level greater than the PSD significance level or, (2) if the existing source is minor for a particular air pollutant and the modification will emit that air pollutant at a level greater than the major new source threshold. Figure 9.2 shows a simplified flow diagram of determining whether a new source or modification is major in an attainment area.

For each pollutant for which the source is considered major, the PSD major NSR permitting process requires that the applicants determine the maximum degree of reduction achievable through the application of available control technologies. Specifically, major sources may have to undergo any or all of the following four PSD steps: (1) Best Available Control Technology (BACT) analysis, (2) monitoring of local air quality, (3) source impact analysis/modeling (i.e. impact on local air quality), and (4) additional impact analysis/modeling (i.e. impact on vegetation, visibility, and Class I areas). The key component of the PSD process

**Figure 9-2 Applicability of New Source Review Requirements
in Attainment Areas for Ozone:
Emissions of NO_x Used as an Example**



Notes:

A Pollution Control Project must be both:

- (a) environmentally beneficial; and
- (b) not cause or contribute to a violation of a NAAQS or PSD increment, or adversely affect an AQRV in a Class I area.

In addition:

- The permitting authority must determine that the project qualifies as a pollution control project.
- The permitting authority must provide an opportunity for public review and comment on the project's application and the proposed NSR exclusion.

is the BACT analysis, which requires that the most stringent control technology available must be used in a facility, unless the applicant can demonstrate that it is not feasible due to energy, environmental, or economic reasons.

Minor sources and modifications are exempt from this rigorous process, but these sources must still obtain construction and operating air permits. Minor sources must demonstrate, through calculations, modeling, vendor guarantees, or other analysis, that the source's emissions will not exceed applicable PSD levels. Many states require even minor sources to complete a BACT analysis and use BACT, although minor sources are usually not required to gather local air quality data or model impacts. New sources or modifications are considered major for NO_x or CO if they exceed the limits shown in Table 9.1.

Table 9-1 Attainment Area Limits for NO_x and CO

Pollutant	New Sources are Considered Major if Emissions Exceed (in TPY)	Modifications to an Existing Minor Source are Considered Major if Emissions Exceed (in TPY)	Modifications to an Existing Major Source are Considered Major if Emissions Exceed (in TPY)
NO_x	250	250	40
CO	250	250	100

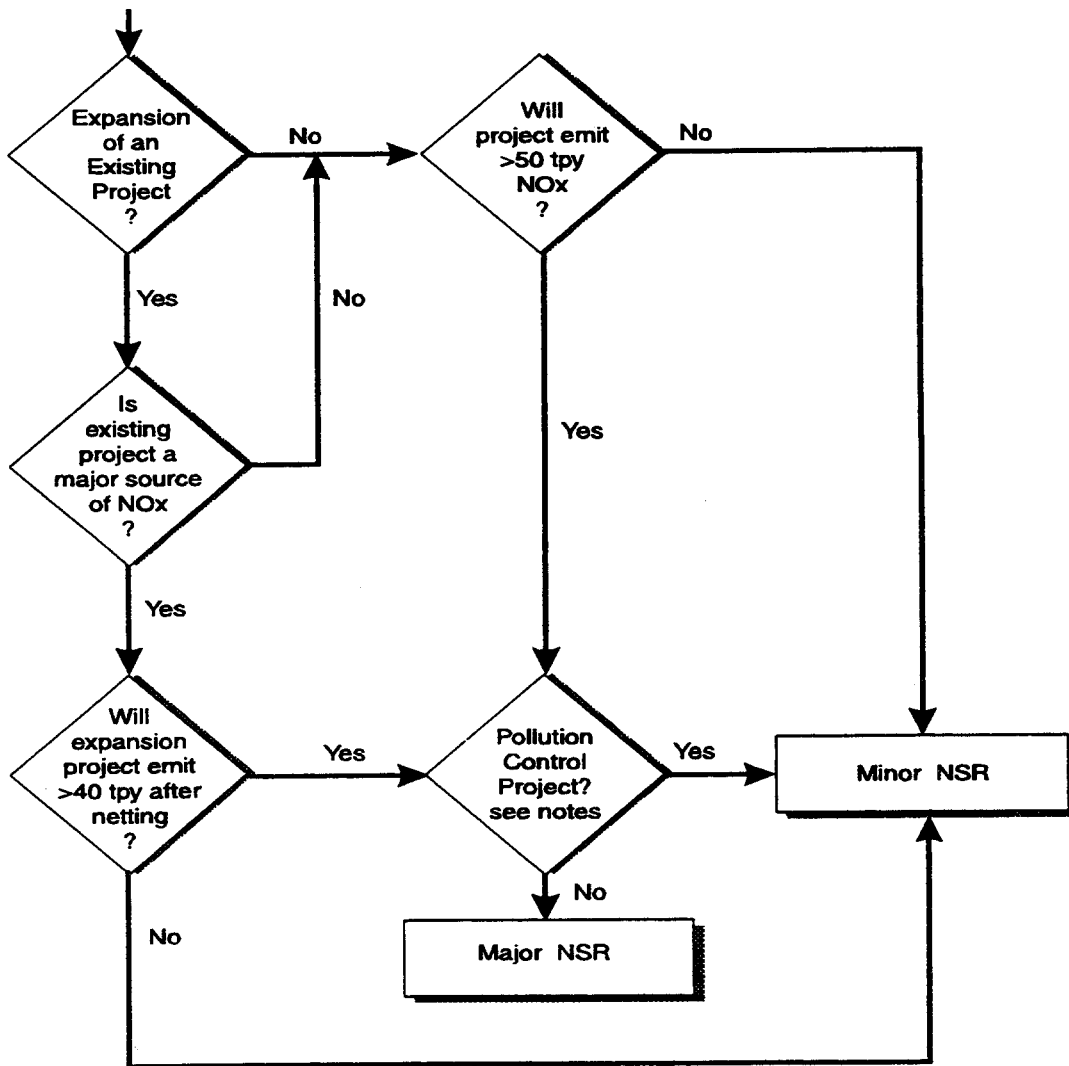
Nonattainment Area Permitting

If a particular area — usually a county-wide area — does not meet the NAAQS levels for any of the six criteria pollutants, then it is classified as being in "nonattainment" for that pollutant. A listing of ozone nonattainment areas is provided in Appendix F, since this is the most pervasive nonattainment pollutant and the most likely to affect landfill energy recovery projects. An area may be nonattainment for one or more pollutants. For example, if a county exceeds the NO_x levels set by the NAAQS, but meets the standards for the other pollutants, then the area is classified as nonattainment for ozone only (since ozone attainment is regulated through NO_x and VOCs).

A proposed new emission source or modification to an existing source located in a nonattainment area must undergo nonattainment major NSR if the source or the modification is classified as major. New sources or modifications are considered major for NO_x or CO if they exceed the limits shown in Table 9.2. Figure 9.3 shows a simplified flow diagram for determining whether a new source or modification is major in a serious nonattainment area.

Two primary requirements must be fulfilled in order to obtain a nonattainment NSR permit for criteria pollutants: (1) The project must use technology that achieves the Lowest Achievable Emissions Rate (LAER) for the nonattainment pollutant, and (2) a source must arrange for an emission reduction at an existing combustion source that more than offsets the emissions from the new project.

**Figure 9-3 Applicability of New Source Review Requirements in
Serious Non-Attainment Areas for Ozone:
Emissions of NO_x Used as an Example**



Notes:

A Pollution Control Project must be both:

- (a) environmentally beneficial; and
- (b) not cause or contribute to a violation of a NAAQS or PSD increment, or adversely affect an AQRV in a Class I area.

In addition:

- The permitting authority must determine that the project qualifies as a pollution control project.
- The permitting authority must provide an opportunity for public review and comment on the project's application and the proposed NSR exclusion.

Table 9-2 Nonattainment Area Limits For NOx and CO

Pollutant	New Sources are Considered Major if Emissions Exceed (in TPY)	Modifications to an Existing Minor Source are Considered Major if Emissions Exceed (in TPY)	Modifications to an Existing Major Source are Considered Major if Emissions Exceed (in TPY)
NOx			
Marginal	100	100	40
Moderate	100	100	40
Serious	50	50	40
Severe	25	25	25
Extreme	10	10	10
CO			
Moderate	100	100	100
Serious	50	50	50

Defining the lowest achievable emission rate (LAER) can be a challenge for landfill gas projects. Permitting authorities unfamiliar with the characteristics of landfill gas may expect a landfill gas project to achieve the same LAER as a natural gas project. This can be difficult for a number of reasons, including the inability of the catalysts designed to reduce NOx emissions to function effectively on landfill gas, the variable flow, composition, and Btu value of landfill gas, and the fact that landfill gas projects are often too small for the use of turbines, which have lower NOx rates than IC engines, to be economic. Cost, however, is not a consideration in determining the LAER technology.

Obtaining emission offsets to ensure no net change in overall pollutant levels can also be a challenge. Emission offsets are created when emission reductions are achieved at an existing emissions source (typically, an industrial facility) in order to cover the increased emissions of the new source. The most common type of offsets required by the new projects are NOx offsets because there are many ozone nonattainment areas (i.e. areas whose NOx and VOC levels do not meet NAAQS), and many combustion sources emit NOx at high enough levels to become major sources and require offsets. Most of the northeast U.S. is designated as an ozone nonattainment area, for example, known as the Northeast Ozone Transport Region.

The number of offsets required by a project is determined by applying an offsets ratio to its emission level above the threshold. The ratio varies from 1:1.1 to 1:1.5 for ozone, depending upon an area's degree of nonattainment, and is 1:1 for CO and other criteria pollutants. For example, a project proposed for a severe ozone nonattainment area that has the potential to emit 100 tons per year of NO_x would be required to obtain 97.5 tons per year of NO_x offsets.³

NSR Exemption for Pollution Control Projects

On July 1, 1994, EPA's Office of Air Quality and Planning Standards issued guidance to regional and state staff that increases their flexibility in permitting projects that are classified as "pollution control projects". Under the guidance, the permitting authority may exempt the project from major NSR, as long as emissions from the project and minor source requirements are met. In nonattainment areas, offsets will still be required, but need not exceed a 1:1 ratio. In order to qualify as a pollution control project, a landfill gas-to-energy project must pass two tests: (1) the environmentally-beneficial test and (2) the air quality impact assessment.

Under the environmentally-beneficial test, the proposed project is evaluated on its overall environmental impact on air quality. If, on balance, there is a beneficial impact on air quality, the project could qualify as a pollution control project. For example, a landfill gas-to-energy recovery project could be considered a pollution control project if it reduces VOCs, even if it generates some NO_x.

Under the air quality impact assessment, the pollution control exclusion will not apply if the emissions from the project would (e.g. NO_x) cause or contribute to a violation of NAAQS or PSD increment, or adversely impact visibility or other Air Quality Related Values (AQRV) in a Class I area [see, e.g., Clean Air Act sections 110(a)(2)(C), 165, 169A(b), 173]. Therefore, where a pollution control project will result in a significant increase in emissions and that increased level has not been previously analyzed for its air quality impact and raises the possibility of a NAAQS, PSD increment, or AQRV violation, the permitting authority is to require the source to provide an air quality analysis sufficient to demonstrate the impact of the project. In the case of non-attainment areas, the State or the source must provide offsetting emissions reductions (at a 1:1 ratio) for any significant increase in a nonattainment pollutant (e.g. NO_x) from the pollution control project. However, rather than having to apply offsets on a case-by-case basis, States may consider adopting specific control measures or strategies for the purpose of generating offsets to mitigate the projected collateral emissions increases from a class or category of pollution control projects.

In addition to passing the two tests, there are two procedural safeguards that a pollution control project must address. First, the project must receive approval from the permitting authority (this is done on a case-by-case basis). Second, the application for exclusion and the permitting agency's proposed decision must be subject to public notice with the opportunity for public and EPA written comment.

³ The number of tons that must be offset is calculated as follows: 3 ["emissions level" (100 tons) minus "threshold level for severe nonattainment" (25 tons)] multiplied by ["offsets ratio for severe nonattainment" (1.3)].

This guidance memorandum is included in Appendix E. It is important to recognize that this is a guidance document and not a promulgated rule, which means that permitting authorities may choose to adopt the guidance and exercise greater flexibility, or disregard it.

NOx Emissions from Energy Conversion

Combustion of landfill gas — in an engine, turbine, or other device — generates nitrogen oxide (NOx). The amount of NOx generated and emitted depends primarily upon the following two characteristics of the combustion process:

- **Air/fuel Ratio:** the ratio of air to fuel (i.e., landfill gas) in the combustion chamber is a key factor in determining the quantity of NOx generated from combustion of landfill gas. If air in excess of what is needed to achieve combustion is introduced into the combustion chamber, fewer NOx emissions are generated.
- **Residence time:** the amount of time that the landfill gas is in the combustion chamber has a significant effect on NOx formation. Longer residence times allow greater quantities of NOx to be formed and ultimately emitted.

The air/fuel ratio and residence time vary between the major technologies used in landfill gas-to-energy applications (i.e., internal combustion engines and combustion turbines) as well as among different types of engines; therefore, NOx emissions per cubic foot of landfill gas burned as fuel in a combustion device also varies. When internal combustion engines and turbines are used in conventional natural gas applications, catalysts are often used to reduce NOx emissions. To date, catalysts have not proven effective in landfill gas applications because the impurities found in landfill gas quickly limit the catalysts' ability to control NOx emissions.

Table 9.3 provides emissions factors that can be used to estimate the range of NOx emissions that could be expected from a landfill gas project employing internal combustion engines (IC) or combustion turbines (CT). As the table indicates, the potential emission factors for IC engines span a relatively large range; the lower end of the range is represented by lean-burn engines, which use excess air in the combustion process, while the high end is represented by naturally aspirated IC engines. Depending on the specific type of engine being used, it should be possible to select an appropriate emission factor from within this range. In contrast, only one emission factor is provided for combustion turbines. This factor is appropriate for the most common type of turbine used for landfill gas applications (the Solar Centaur gas turbine).

Table 9-3 Emission Factors By Technology Type

	IC Engine	CT
Emission factor (lb NO _x /MMBtu)	0.22 - 0.54	0.12

Annual NO_x emissions can be calculated by multiplying the appropriate emission factor from Table 9.3 by the energy content (in MMBtu/year) of the landfill gas fuel. The energy content can be calculated easily from the landfill gas flow, as follows:

$$\text{Energy Content (Btu/Yr)} = \text{LFG (cfd)} \times \frac{\text{Btu}}{\text{cf}} \times \frac{365 \text{ days}}{\text{yr}}$$

Landfill gas typically contains about 500 Btu per cubic foot. This can be used as a default if the Btu value of landfill gas at a specific site is not known. For a 5 million ton landfill with a gas flow of about 3 million cubic feet per day, the energy content would therefore be calculated as follows:

$$3 \text{ mmcf/d} \times \frac{500 \text{ Btu}}{\text{cf}} \times 365 = 548 \times 10 \text{ MMBtu/yr}$$

Table 9.4 illustrates a potential range of emissions in tons of NO_x per year for typical 1, 5, and 10 million ton landfills. As Table 9.4 illustrates, NO_x emissions from IC engines are substantially higher than emissions from CTs. Landfills located in ozone non-attainment areas may therefore find that CTs are the most appropriate technology for medium or larger sized landfill gas projects. The following sections describe the differences among IC engines and between IC engines and CTs that result in the large range of emissions.

Table 9-4 NO_x Emissions Table

Landfill Characteristics		Estimated NO _x Emissions (TPY)	
Waste in Place (million ton)	Landfill Gas Flow (1000 cfd)	IC Engine	CT
1	642	13 - 32	n/a
5	2988	60 - 147	35
10	5264	106 - 260	60

Internal Combustion Engines — There are two basic types of IC engines: naturally aspirated and lean-burn. Naturally aspirated IC engines draw combustion air and landfill gas through a carburetor in stoichiometric proportions, much the same way that an

automobile equipped with a carburetor would draw its air/fuel mixture. Just enough air is drawn into the combustion chamber to ignite the air/landfill gas mix. In addition, residence time in the combustion chamber is relatively long. Therefore, this type of engine emits relatively high levels of NO_x, and is represented by the high end of the range shown in Table 9.4. For landfill gas-to-energy recovery projects, this type of engine is best suited for smaller projects in ozone attainment areas.

Lean-burn IC engines combust landfill gas with air in excess of the stoichiometric mix. Since this type of engine uses a mixture with excess air, it provides both greater engine power output and fewer NO_x emissions than a comparable naturally aspirated engine. This type of engine can be expected to emit NO_x emissions on the low end of the range shown in Table 9.4. It should be noted that manufacturers of these engines are continually refining them and that newer, even lower NO_x emitting engines are expected to be commercially available soon. In addition, newer, more effective add-on control systems are in development.

Combustion Turbines — CTs utilize large amounts of excess air and have relatively short residence time. These factors combine to greatly reduce the amount of NO_x emitted relative to internal combustion engines. These lower emissions may be a significant benefit of using a CT, particularly for medium to large landfill gas energy recovery projects located in ozone nonattainment areas. However, because CTs are not cost-effective at smaller projects (i.e., less than 3 MW), these projects typically do not have the option of using CTs.

9.4 LOCAL ISSUES

Local approval of a project is crucial to its success. This approval refers not only to the granting of permits by local agencies, but also to community acceptance of the project. Strong local sentiment against a project can make permitting difficult, if not impossible.

9.4.1 Zoning and Permitting

Project siting and operation are governed by local jurisdictions (in addition to federal regulations); therefore, it is imperative to work with regulatory bodies throughout all stages of project development in order to minimize permitting delays which cost both time and money. This is especially important since the pollution prevention benefits of landfill gas projects may not initially be considered and because different agencies' rules can often be conflicting [Pacey, Doorn, Thorneloe, 1994].

Zoning/Land Use

The first local issue to be addressed is the compatibility of the project site with community land use specifications. Most communities have a zoning and land use plan that identifies where different types of development are allowed (e.g., residential, commercial, industrial). The local zoning board determines whether or not land use criteria are met by a particular project, and can usually grant variances if conditions warrant.

A landfill gas project site will likely require an industrial zoning classification. One advantage of landfill gas projects is that they are usually located at the landfill site, thus zoning reclassification may not be necessary, especially if the landfill is still active.

Permitting Issues

In addition to land use specifications, local agencies have jurisdiction over a number of other project parameters, such as the following:

Noise — Most local zoning ordinances stipulate the allowable decibel levels for noise sources, and these levels vary, depending on the zoning classification at the source site (e.g., a site located near residential areas will have a lower decibel requirement than one located in an isolated area). Even enclosed facilities are usually required to meet these requirements; therefore, it is important to keep them in mind when designing project facilities.

Condensate — There may be unique permitting or treatment requirements for landfill gas condensate. While some landfill gas projects can return the condensate to the landfill, many dispose of condensate through the public sewage system after some form of on-site treatment [Berenyi and Gould, 1994]. It is possible that the condensate may contain high enough quantities of heavy metals and organic chemicals for it to be classified as a hazardous waste, thus triggering additional, federal regulation.

Wastewater — The primary types of wastewater likely to be generated by a landfill gas power project include maintenance/cleaning wastewater, domestic wastewater, and cooling tower blowdown. The municipal engineer's office should be contacted to provide information about available wastewater handling capacity, and any unique condensate treatment requirements or permits for landfills. The wastewater treatment facility operator is likely to have standards governing the pollutant concentrations in incoming wastewater streams. For projects that intend to discharge wastewater into rivers, lakes, or other surface water (typically only the large power projects that use a steam cycle), a National Pollution Discharge Elimination System (NPDES) permit will be required. The authority to issue these permits is delegated to state governments by the U.S. EPA.

Water — Water requirements will depend on the type and size of the project and the environmental control technologies used. The city engineer's office should also be able to provide data about available water supply capacity. If current facilities cannot meet the needs of the project, then new facilities (e.g., pipeline, pumping capacity, wells) may need to be constructed. Groundwater permits could be required if new wells are needed to supply the project's water needs. (Note that the landfill itself, if active, will already be required by RCRA Subtitle D to monitor groundwater.)

Solid waste disposal — The only solid wastes generated by a landfill gas power project will likely be packaging materials, cleaning solvents, and equipment fluids. While there may only be a small amount of solid waste generated, it must be properly disposed of; which may be an important consideration if the project landfill is closed.

Stormwater management — Public works departments regulate stormwater management, and will require a permit for discharges during construction and operation. Good facility design that maintains the predevelopment runoff characteristics of the site will allow the project to easily meet permitting requirements.

Stack height — Local codes may limit stack heights, especially near airports or landing fields. Project design (e.g., plant layout, flare design) must take these limits into account.

Other — There may be other issues that local agencies oversee. It is important to find out what these issues are by contacting local authorities, especially since they vary among project sites. As an example of such other issues, Box 9.1 partially lists the local permits that were required for the Fresh Kills Landfill Methane Recovery Project, located in New York.

9.4.2 Community Acceptance

As any project developer will attest, community support is extremely important to the success of a project, especially since some communities require public participation in project zoning/siting cases. Like landfills, many power projects in the past have encountered local opposition such as the "not in my backyard (NIMBY)" syndrome, or false perceptions of project dangers (e.g., explosion risks, adverse health effects from electromagnetic fields). Therefore, it is important to educate the public and to develop a working relationship with the host community in order to dispel any fears or doubts about the expected impact of the project. Project details should always be presented in a very forthcoming and factual manner.

Landfill gas-to-energy projects bring many benefits to the host community (e.g., improved air quality, reduction of landfill gas odor and explosive potential). These benefits should be emphasized during the permitting process.

Box 9-1 Some of the Local Permits Required for the Fresh Kills Landfill Methane Recovery Project

<u>Agency</u>	<u>Permits</u>
Bureau of Gas and Electricity	Certification that all equipment is explosion proof
Division of Fire Protection	One hundred percent x-ray of all pipe joints
Department of Sanitation	Site approval
Board of Standards and Appeals	Approval of equipment on site
Community Planning Board of Staten Island	Compliance with height restrictions
Department of Environmental Protection	Air Quality approval
Department of Ports and Terminal	Well permits
Department of Buildings	Construction approvals

Source: "Regulatory Barriers to Landfill Gas Recovery Projects"

10. Contracting For EPC And O&M Services

As discussed in Chapter 7, many landfill owners may decide to work with firms with extensive experience during project development. Likewise, because the construction and operation of landfill gas energy recovery projects are complex processes, they may be best managed by a firm with proven experience, gained over the course of implementing similar landfill gas projects. Landfill owners that choose to contract with an engineering, procurement, and construction (EPC) firm and/or an operating firm should be aware of some of the basic elements of effective contracting. This chapter provides some contracting considerations for landfill owners, and lists operating insights gained from a survey of technical literature and interviews with landfill energy project owners, developers, and operators.

10.1 EPC/TURNKEY CONTRACTING

After a project proponent has secured an energy sales contract and the required permits and approvals, he or she may contract with an EPC or turnkey firm who will take responsibility for construction of the project.

The tasks performed by an EPC contractor include: conducting engineering design, procuring the equipment, preparing the project site for construction, and pre-operation start-up testing. A turnkey contractor extends its services beyond those of an EPC contractor by taking on many of the owner's and developer's duties as well, which include environmental permitting, regulatory licensing, interconnections, and project management.

The process of contracting with an EPC or turnkey firm is charted in Figure 10.1. As this figure shows, the process has several key steps, beginning with the landfill owner and/or project developer soliciting bids from contractors and ending with the selection of a contractor who will take the project to commercial operation. Along the way, the owner/developer and its chosen contractor must conduct engineering design, site preparation, and plant construction.

An effective EPC or turnkey contract clearly establishes the responsibilities of each contracting entity, and it also should mesh with other existing project documents. The contractor is generally responsible for engineering and building the plant to predetermined specifications, making sure that project construction milestones are met, and ensuring that acceptable performance is achieved at the commercial operation date. The landfill owner

The Project Development Process

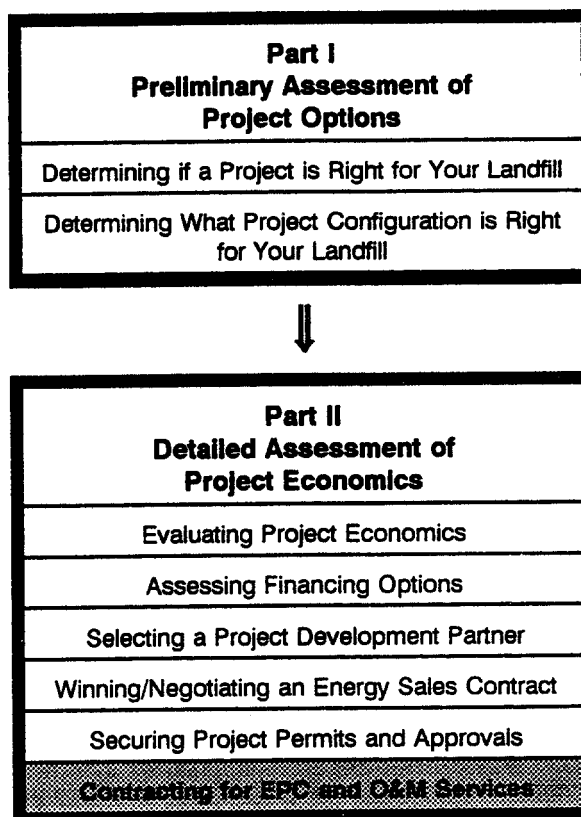
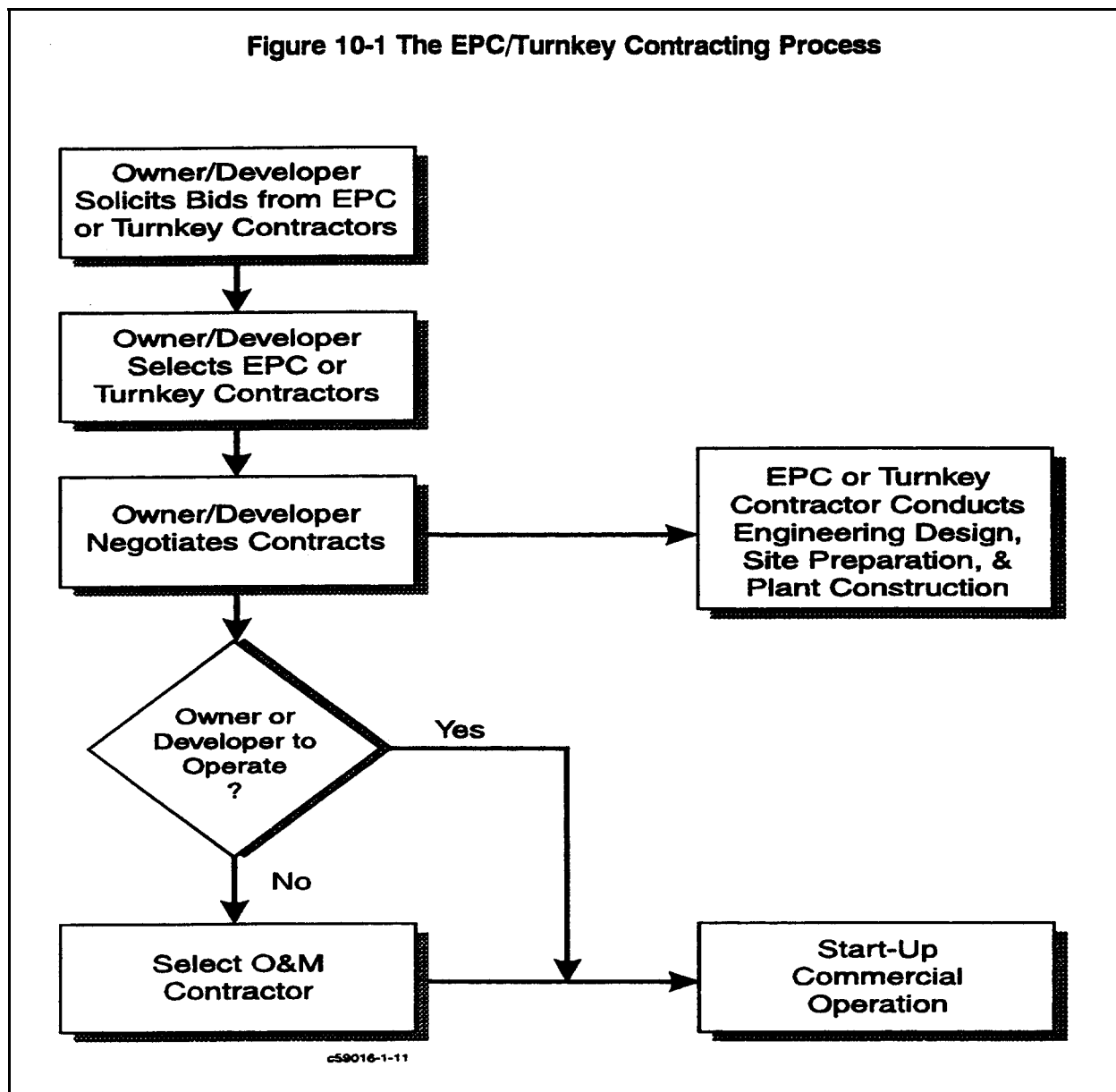


Figure 10-1 The EPC/Turnkey Contracting Process



and/or project developer is generally responsible for making sure funds are available as needed, that the site is available and ready, and that provisions are made for any necessary interconnections related to gas utilization. The elements of an effective contract are described in Table 10.1.

Because of the importance of securing and fulfilling the power sales agreement, the EPC contract should specifically recognize each entity's role in meeting its key elements. These elements include:

Table 10-1 Elements of an Effective EPC or Turnkey Contract

Element	Items to be Specified
Commercial operation date	Date on which facility should achieve commercial operation (should precede date in Power Sales Agreement (PSA))
Milestones	Engineering completion, construction commencement, engine delivery, start-up
Cost, rates, and fees	Structures include: fixed EPC or turnkey price, hourly labor rates, cost caps, fee amount or percentage
Performance guarantees	Specified output (kW, mcf), heat rate, availability, power quality, gas quality (should match PSA)
Warranties	Output, performance degradation, heat rate, outage rates, component replacement costs
Owner's acceptance criteria and procedure	Testing methods and conditions, calculation formulae
Bonus amounts and conditions	Bonus for early completion, exceeding specifications
Liquidated damages and conditions	Damages for late completion, failure to meet specifications
Assignment	Ability to assign agreement to subsidiary, partnership, bank

- Commercial operation date;
- Project output (e.g., kW electricity, mcf gas) and heat rate;
- Plant availability; and
- Interconnection requirements; and
- Maintenance provisions.

Power project developers usually prefer to sign fixed-price EPC or turnkey agreements, which enable the plant's installed cost to be known up front. If a fixed-price contract is selected, then the price, scope of services, and other terms must be clearly specified in the contract. The contract price should have an underlying budget that includes plant components as well as the services mentioned above. The most important budget items are listed in Box 10.1.

Contracting with a turnkey plant provider is an extension of contracting for EPC services, because the turnkey provider usually agrees to include within its scope of services the owner's and developer's duties as well as EPC contracting. A turnkey plant provider is usually an EPC firm or developer who agrees to develop and build a facility for a fixed price. As shown in Table 10.1, a turnkey contract must include the following items that are in addition to the typical EPC contract items: turnkey price, development milestones, and contractor's responsibilities.

Box 10.1 EPC and Turnkey Budget Items

The EPC budget for a landfill gas energy recovery project should include at least the following items:

- Engine skid (e.g., IC engine, CT, turbine/generator)
- Engine auxiliaries (e.g., lubricating oil system, cooling system, air intake manifold and filters, intake and exhaust silencers, fuel injection system, hydraulic system, piping, and ductwork)
- Foundations and sitework
- Gas processing system (e.g., filters, refrigeration)
- Gas compressor(s)
- Emissions controls
- Plant electrical equipment and switchgear
- Step up transformer(s)
- Interconnections (electric, water, landfill gas)
- Back-up fuel capability/storage
- Automatic control system
- Gas and electric metering
- Water treatment and cooling
- Building/enclosure
- Fire protection system
- Engineering costs and associated expenses
- EPC contingency

A turnkey facility provider should include the following additional items:

- Gas collection system (if applicable)
- Additional interconnection costs (e.g., rights-of-way, piping, transmission lines)
- Permitting costs, legal, administration expenses, insurance
- Financing costs (if applicable)
- Escalation during construction
- Interest during construction
- Contingency
- Fee

10.2 O&M SERVICES CONTRACTING

Many landfill owners and/or project developers do not wish to take on the day-to-day responsibility of operating their landfill gas energy recovery project due to lack of manpower, experience, or desire. When this is the case, hiring an O&M contractor may be an attractive alternative. A survey of existing and planned landfill gas energy recovery projects shows that about 80% of gas collection systems and 89% of gas processing/energy recovery systems are operated by private O&M firms or in partnership with a private O&M firm [Berenyi and Gould, 1994].

When contracting with the provider of O&M services, the landfill owner should talk to several competing companies and select a winner based on experience, price, and terms. The O&M company should have experience operating and maintaining similar facilities, and should demonstrate that its accumulated experience will be applied in the form of qualified personnel and ongoing training activities. Competing O&M companies should be asked to submit hourly rates, expected annual budgets for O&M services, and fees.

It is important that the scope of O&M services be well defined so all bids can be compared on a consistent basis. For example, it should be clearly specified whether O&M services are to be provided for the gas collection system and the energy recovery system both or only for one. The EPC contractor or equipment vendor can usually supply estimates for the costs and duration of periodic maintenance procedures and major overhauls.

The facility owner may choose to provide incentives to the O&M company in the form of contractual bonus/damages clauses to improve performance. For example, if maximizing annual operating hours is important to project economics, then the facility owner might propose a cash bonus for plant availability or kWh generation which exceeds a predetermined amount.

10.3 GOOD O&M PRACTICES

The power production and direct use technologies for landfill gas have been improved since their first use about 15 years ago. Over this time, many of the operational problems encountered have been addressed with technology or procedural improvements. Therefore, many of the technical problems found in the landfill gas literature are no longer major obstacles to successful landfill gas energy recovery (in fact, some of the problems are no longer obstacles at all).

In a recent survey, however, at least 22% of operating landfill gas energy recovery projects reported experiencing operating interruptions for reasons other than planned maintenance [Berenyi and Gould, 1994]. Of the 29 plants that reported unplanned interruptions, only two experienced problems resulting in plant failure. The main reason cited for interruptions was gas collection or processing equipment problems. Other specific operational problems related to the gas collection system causing plant interruptions include pipe blockage or breakage and lack of landfill gas. In many cases, such problems can be avoided with careful equipment selection and operation and maintenance. Good O&M procedures are always important to the success of energy projects. They are even more important with landfill gas projects due to the impurities and variability found in landfill gas. This section presents insights on how to prevent or minimize operating problems.

10.3.1 Collection Systems

Before sizing an energy recovery project, a project developer should estimate landfill gas quantity as accurately as possible to prevent oversizing the equipment and inefficiencies due to gas shortfall during operation. After project start up, proper operation and maintenance of the gas collection system is necessary to balance offsite gas migration control with optimal equipment performance.

Collection system problems may occur when wellfields are located in active landfill areas; therefore, it is important to account for future landfill operations when designing the

collection system. By planning ahead, plant shutdowns or reduced output levels due to collection system repairs may be avoided. Two examples of potential problems that may be prevented by good planning are:

- Decreased gas recovery rates due to limited well accessibility caused by depositing additional refuse vertically on top of existing wells [WMNA, 1992];
- Reduced landfill gas generation and quality caused by reopening a section of inactive landfill where an existing well is located.

Good operating procedures, in addition to good system design, will also help to prevent problems. For example, routine monitoring and tuning of wells will ensure that gas quality is suitable for the efficient operation of the recovery equipment.

10.3.2 Energy Recovery Systems

While energy recovery technologies have been adapted to landfill gas applications, several important operating considerations must be kept in mind to minimize or avoid problems that arise due to landfill gas's corrosive nature and low Btu content.

IC Engines

IC engines are the most susceptible of the three common electric generation technologies to the effects of corrosion [Anderson], which attacks engine parts and causes deposit buildup. Experience has shown the following steps to be useful in combatting corrosion in IC engines used at landfills:

- Perform frequent oil checks and changes.
- Use an oil with a high alkalinity reserve (i.e., oil with a high total base number) [Schleifer, 1988]. Oils with a total base number (TBN) of 10 are commonly used [WMNA, 1992].
- Use oil filters that have been treated with chemicals to neutralize acids from the combustion of landfill gas [Anderson].
- Chrome-plate components that are subject to attack [Pacey, Doorn, and Thorneloe, 1994].

CTs and Boiler/Steam Turbines

Although CTs and boiler/steam turbines are more resistant to corrosion than engines, they each have their own set of operational considerations:

- An extra filtration step may be necessary if the compressors used to reach the required pressure for CT operation cause oil entrainment and heating of the landfill gas [WMNA, 1992].
- Due to the Btu variability in landfill gas, CT fuel/air controls must react very quickly. If they do not, the temperature will overshoot and automatically shut

down the CT. To avoid temperature overshoot, landfill gas fueled-CTs should be operated at a lower temperature setpoint than CTs using conventional fuels [Pacey, Doorn, and Thorneloe, 1994].

- Silica deposits, which can lead to turbine failure, can be prevented with gas refrigeration to condense dimethyl siloxane before combustion; however, this step may not be economically justified [Anderson, WMNA, 1992].
- Boiler tubes should be designed to withstand the corrosiveness of landfill gas.

The over 200 existing and planned landfill gas energy recovery projects illustrate that the technology is well-demonstrated and generally reliable. As long as projects are well planned, executed, and maintained, they can perform up to or beyond expectations for many years.